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(54) Alternating current generator.

(57) An alternating current generator for supplying the electrical loads on a motor vehicle comprises a stator core (16) that carries a three-phase stator or output winding (18), a rotor (20) having two claw pole members (30,32) that are magnetically connected by a core (34). A field coil (38) is disposed about the core. Pole fingers (30B,32B) of the claw pole members are interleaved and have a plurality of permanent magnets (54) secured to their side surfaces, such that there is a permanent magnet between each pair of adjacent pole fingers. The generator is arranged such that flux developed by the permanent magnets (54) can flow through a closed magnetic path that bypasses an air gap between the rotor and stator and such that energization of the field coil with unidirectional current causes permanent magnet flux to traverse the air gap between the rotor and stator and thereby provide a useful flux for generating voltage in the stator winding.

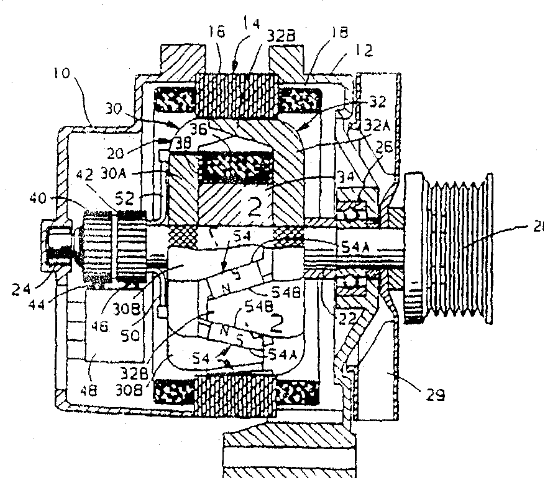

FIG. 1

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ALTERNATING CURRENT GENERATOR

This invention relates to alternating current generators for use, for example, in supplying electrical power to the electrical loads of a motor vehicle and in charging the vehicle storage battery.

Since motor vehicles have ever increasing power demands, an alternator with greater electrical output, higher power to weight ratio and better conversion efficiency is needed.

This invention proposes to increase the power output of an alternating current generator by utilizing a Lundell rotor for the generator that has a field coil and a plurality of permanent magnets that are interposed between adjacent pole fingers of claw tooth pole members.

Alternating current generators that use permanent magnets and control windings are disclosed in the United States patent to Rosenberg 3,411,027. In that patent, field flux diverted by the control windings is carried by the end frames and a tubular frame connecting the end frames and the control windings are stationary. This type of construction leads to large heavy machines.

According to an aspect of the present invention, there is provided an alternating current generator as defined in claim 1.

The flux developed by the permanent magnets can pass through a closed magnetic path that is formed substantially of magnetic material. This path comprises the two claw-pole members and a core that engages the claw pole members. This closed magnetic path shunts or bypasses the air gap between the rotor and stator so that, except for leakage flux, the flux developed by the permanent magnets does not link the stator winding. When the field coil is energized with current, the magnetomotive force (mmf) developed by the field coil opposes the permanent magnet (mmf) in the closed magnet circuit and thereby causes the permanent magnet flux to cross the air gap between the rotor and stator and link the stator winding. Thus, the current generator can control both field flux and permanent magnet flux by means of the field current, which is preferably unidirectional. Additionally, the field current can be controlled by a conventional switching voltage regulator.

An embodiment of the present invention is described below, by way of illustration only, with reference to the accompanying drawings, in which:

Figure 1 is a sectional view of an embodiment of alternating current generator;

Figure 2 is a sectional view taken along line 2-2 of Figure 1;

Figure 3 is a perspective view of a modified rotor for an alternating current generator, and; lating arrangement for controlling field current of an alternating current generator.

Referring now to the drawings and more particularly to Figure 1, the alternating current generator comprises metal end frames 10 and 12 that support a stator assembly 14. These end frames are typically formed of aluminium. A plurality of through-bolts (not illustrated) are used in a known manner to secure the end frames together. The stator assembly 14 comprises a slotted stator core 16 formed of a stack of steel laminations that carries a three-phase stator or output winding 18. Portions of the stator winding 18 are located in the slots of stator core 16 as is well known to those skilled in the art.

The alternating current generator has a rotor generally designated by reference numeral 20. This rotor comprises a shaft 22 that is supported for rotation by bearings 24 and 26. A pulley 28 is connected to shaft 22 and a cooling fan 29 is secured to the shaft.

The rotor 20 further comprises claw pole members 30 and 32 and an annular core 34, all of which are secured to shaft 22 to rotate therewith. The ends of core 34 respectively engage pole members 30 and 32. Pole members 30 and 32 and core 34 are all formed of magnetic material such as steel.

The core 34 supports a field coil 36 that is carried by a spool 38 that is formed of insulating material. The spool and field coil form part of the rotor and rotate relative to the stator whenever the rotor is rotated.

The rotor shaft 22 carries metallic slip rings 40 and 42 that are electrically insulated from each other and from shaft 22. The slip rings are engaged by brushes 44 and 46 that are supported by brush holder 48. The slip ring 40 is connected to one side of field coil 36 by a conductor 52. The opposite side of field coil 36 is connected to slip ring 42 by a conductor 50.

The rotor pole members 30 and 32 are identical. Pole member 30 has a disc portion 30A and six circumferentially spaced and axially extending pole fingers 30B. Pole member 32 has a disc portion 32A and six circumferentially spaced and axially extending pole fingers 32B. It can be seen that the pole fingers 30B and 32B are interleaved, that is, pole fingers 30B are located in spaces between pole fingers 32B and vice-versa.

The rotor has twelve permanent magnets each of which is designated as 54. Each permanent magnet 54 has opposed end faces 54A and 54B that engage respective side surfaces on pole fingers 30B and 32B. The sides of permanent mag-

formed in pole fingers 30B and 32B shown in Figure 2. The permanent magnets are press-fitted into the grooves or slots and may be secured to the pole fingers by a suitable adhesive. The faces 54A and 54B have opposite magnetic polarities. Thus, it will be assumed in the further description of this invention that faces 54A have a south magnetic polarity and that faces 54B have a north magnetic polarity.

Although only two permanent magnets 54 have been shown in Figure 1, it is to be understood that 12 magnets are used, and that there is a permanent magnet 54 between each pair of opposed side surfaces of pole fingers 30B and 32B. Further, the permanent magnets are arranged such that the opposed sides of pole fingers 32B are respectively engaged by magnet surfaces 54B of a north magnetic polarity and opposed sides of pole fingers 30B are engaged by magnetic surfaces 54A of a south magnetic polarity. This arrangement causes all the pole fingers 32B to have a north magnetic polarity and all the pole fingers 30B to have a south magnetic polarity.

The field coil 36 of the generator, shown in Figure 1, is energized with unidirectional current by a voltage regulating arrangement that is shown in Figure 4. In Figure 4, output winding 18 is shown as being Delta-connected but it could be Y-connected if so desired. The stator or output winding 18 is connected to a three-phase, full-wave bridge rectifier 60 having a positive direct voltage output terminal 62 and a grounded negative direct voltage output terminal 64. The positive terminal 62 is connected to the positive terminal of storage battery 66 by line 68.

Unidirectional current is supplied to field winding 36 by line 70 and a field effect transistor 72 which forms a part of a conventional generator voltage regulator. The drain of transistor 72 is connected to line 70 and its source is connected to one side of field coil 36 through slip ring 42. The opposite side of field coil 36 is grounded through slip ring 40 and a field discharge diode 74 is connected across field winding 36. The gate of transistor 72 is connected to a voltage sensing circuit identified as VS. The voltage sensing circuit is connected between the positive side of battery 66 and ground and it accordingly senses the voltage across battery 66. The voltage regulator is of the type disclosed in the United States patent to Bowman et al. 4,636,706. When the voltage between line 68 and ground is above the desired regulated value, the voltage sensing circuit VS causes transistor 72 to be shut-off or nonconductive to cut-off field current to field winding 36. When the voltage between line 68 and ground is below the desired regulated value, the transistor 72 is pulse-width modulated on and off to provide a field current that tends to increase the voltage on line 68 toward the desired regulated value. When the voltage on line 68 increases to a level where it exceeds the desired regulated value, transistor 72 shuts off. The pulse-width modulated control of field current is explained in above-referenced US patent 4,636,706.

The field coil 36 is so wound and the direction of the current flow therethrough is such that disc portion 32A and pole fingers 32B have a north magnetic polarity and the disc portion 30A and pole fingers 30B have a south magnetic polarity. This is under the assumption that permanent magnets 54 have the magnetic polarities described above.

When no current is supplied to field coil 36, the flux developed by each permanent magnet 54 will flow from its north pole (face 54B) to its south pole (face 54A) in a path that is made up entirely of steel or iron with no air gaps in this path. The path is from a face 54B of a magnet 54 to a pole finger 32B, through disc portion 32A to pole core 34 and then through pole core 34, disc portion 30A and a pole finger 30B to a face 54A of a magnet 54. The flux path has been described for only one magnet 54 and it will be apparent that the flux path is the same for all twelve magnets. The flux developed by the permanent magnets 54 is retained within the rotor and does not link with the output winding 18 except for a small quantity of magnetic leakage flux. Accordingly, the voltage induced in stator winding 18 is small. The flux path that has been described can be considered as diverting or shunting the permanent magnet flux away from the air gap between the rotor and stator core 16. Since pole fingers 30B and 32B form a shunt magnetic path, their cross-sectional areas are chosen such that they are large enough to carry the permanent magnet flux.

Assume now that field coil 36 is energized. With the polarities of the permanent magnets and field coil, as has been described, the flow of permanent magnet flux through pole fingers 30B and 32B and core 34 is determined by the magneto-magnetic force developed by field coil 36. The magneto-magnetic force developed by field coil 36 opposes the magneto-magnetic force developed by the permanent magnets in the closed magnetic circuit formed by pole members 30 and 32 and core 34. Having regard to the development of a magneto-magnetic force by field coil 36, it will be appreciated that the magneto-magnetic force between pole fingers 30B and 32B varies as field current is varied, and is zero with no field current. This magneto-magnetic force determines the flux that flows through a path that includes pole fingers 32B, through the air gap to stator core 16, through the air gap between stator core 16 and pole fingers

30B, and then from pole fingers 30B through disc portion 30A and pole core 34. Permanent magnet flux can flow in two paths, the first path, which diverts flux from the air gap between the rotor and stator, being through pole fingers 30B and 32B and through core 34. The other path is from pole fingers 32B to stator core 16 and through stator core 16 to pole fingers 30B. From what has been described, it will be apparent that fluxes developed by the permanent magnet and by the field coil both link stator output winding 18 so that both fluxes now serve to cause a voltage to be induced in winding 18. The amount of permanent magnet flux that is diverted away from the stator core 16 depends on the amount of magneto-magnetic force developed by field coil 36. When there is no current supplied to field coil 36, all of the permanent magnet flux except for leakage is diverted away from stator core 16 because it flows through the previously described closed iron path, including pole fingers 30B and 32B and core 34. As field coil 36 is energized, less permanent magnet flux is diverted away from stator core 16. The amount of permanent magnet flux that is diverted away from stator core 16 will depend upon the magnitude of the magneto-magnetic force developed by field coil 36 which, in turn, depends upon the magnitude of field current supplied to field coil 36. At some intermediate level of field coil magneto-magnetic force, none of the flux developed by permanent magnets 54 is diverted away from stator core 16. As field coil magneto-magnetic force is further increased, all the permanent magnet flux plus field coil flux, less leakage, is delivered to stator core 16. Thus, the total air gap flux can be controlled from some near zero minimum to some maximum design value. In a practical application, the system may be configured such that at maximum field current, the total useful flux that links output winding 18 can be made up of 40% permanent magnet flux and 60% field coil flux.

It will be appreciated that the output voltage of output winding 18 can be maintained at a desired regulated value by the simple voltage regulating arrangement shown in Figure 4 which supplies unidirectional current to field coil 36. Thus, when the output voltage of output winding 18 is below the desired regulated value, field current is increased. A field current increase has a two-fold effect in increasing generator output voltage; that is, it causes less permanent flux to be diverted away from stator core 16 and it causes an increased field coil flux to link output winding 18 due to increased field current. When the output voltage of output winding 18 exceeds the desired regulated value, field current is reduced which reduces air gap flux. By using the generator structure in Figure 1, which is capable of variably diverting permanent flux away from stator core 16 the simple voltage regulating arrangement shown in Figure 4, can regulate the output voltage of the generator. There is no need to reverse the direction of current flow through field coil 36 to regulate the output voltage of the generator. Regulation is accomplished by supplying a variable unidirectional current to field coil 36.

The concept disclosed above can be extended to alternators having twin rotor sections consisting of two back to back Lundell rotors on a common shaft. Figure 3 illustrates such a rotor construction that can be substituted for the rotor of Figure 1. The rotor of Figure 3 uses two rotors supported by a common shaft 78 where each rotor is like the rotor shown in Figure 1. One of the rotors comprises pole fingers 80 and 82 with permanent magnets 84 interposed therebetween. This rotor has a field coil and core like the ones in Figure 1, but which are not illustrated here. The other rotor comprises pole fingers 86 and 88 with permanent magnets 90 interposed therebetween. This rotor also has a field coil and core like the ones in Figure 1, but which are not illustrated here. The Figure 3 rotor is constructed like the rotor shown in Figures 8 and 9 of US Patent No 4,882,515, which is incorporated herein by reference, but is modified to the extent that a permanent magnet of the US-4,882,515 rotor is replaced with field coil 90. Each of the rotors operates like the rotor shown in Figure 1.

The two field coils of the rotor shown in Figure 3 can be regulated by the system shown in Figure 4. That is, the two field coils can be connected in series or in parallel and, thus, powered via transistor 72. The manner of connecting the field coils in series or in parallel is shown in Figures 6 and 7 of US Patent 4,882,515.

It will be appreciated that when the dual rotor of Figure 3 is used as a component of an alternating current generator, the length of the stator core 16 must be increased to accommodate the two rotors. The advantage of the construction shown in Figure 3 is that greater output power can be obtained for a given rotor diameter.

Claims

1. An alternating current generator comprising, a stator (14) including a stator core (16) formed of magnetic material and having slots therein; an output winding (18) including one or more conductors disposed within the slots of the stator core; a rotor (20) rotatably disposed within the stator core such that an air gap is provided between the rotor and the stator core, the rotor comprising a shaft (22), first and second members (30,32) formed of mag-

netic material carried by the shaft, the first member (30) having a plurality of first fingers (30B) spaced from one another and extending substantially axially of the rotor, the second member having a plurality of second fingers (32B) spaced from one another and extending substantially axially of the rotor, wherein the first and second plurality of fingers are interleaved, a rotor core (34) formed of magnetic material carried by the shaft, interposed between the first and second members and having one end engaging the first member and a second and engaging the second member; a field coil (36) disposed around the rotor core; first and second slip rings (40,42) carried by the shaft and electrically connected to opposite ends of the field coil; first and second brushes (44,46) engaging the slip rings and adapted to be connected to a source of current to energize the field coil; a plurality of permanent magnets (54) each of which has a first face engaging a surface of a first pole finger and a second face engaging a surface of a second pole finger, the faces of the permanent magnets having opposite magnetic polarities and being so oriented that magnet faces of like magnetic polarity respectively engage opposed surfaces of a given pole finger, the first and second members and the rotor core defining a closed magnetic circuit formed substantially entirely of magnetic material; the magnetic circuit being adapted substantially to shunt the air gap between the rotor and stator core, whereby the flux developed by the permanent magnets is diverted from the air gap by the magnetic circuit and substantially only leakage flux developed by the permanent magnets traverses the stator core when the field coil is not energized, the field coil, when energized with current, being adapted to develop a field magneto-magnetic force in the magnetic circuit which opposes the magneto-magnetic force developed in the magnetic circuit by the permanent magnets, whereby flux developed by the permanent magnets is caused to traverse the air gap through a path that includes adjacent first and second fingers, the flux developed by the field coil traversing the air gap and being applied to the stator core by the first and second fingers, the amount of permanent magnet flux applied to the stator core being dependant upon the magnitude of the current applied to the field coil.

2. An alternating current generator according to claim 1, comprising voltage regulating means (VS) for maintaining the output voltage of the generator at a desired regulated value, the regulating means applying direct field current to the field coil in only one direction through the field coil, and including means for varying the magnitude of the direct field current as an inverse function of the output voltage of the generator.

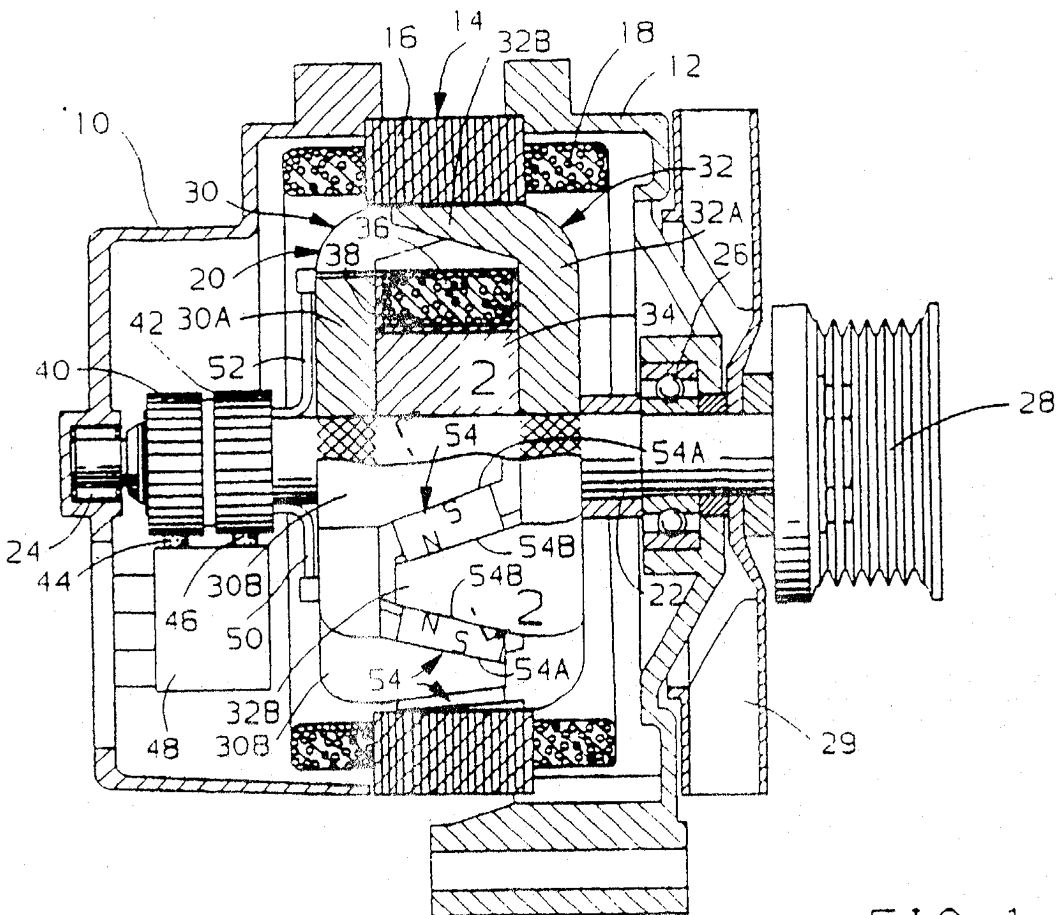
10
16
14
32B
18
12
30
32
36
32A
20
38
26
30A
34
42
52
2
28
40
54
54A
24
N
S
44
54B
30B
54B
46
22
50
N
S
2
54A
48
54
32B
29
30B

FIG. 1

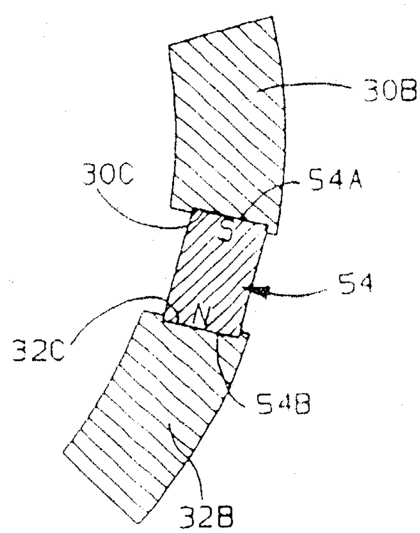
30B
30C
54A
S
54
N
32C
54B
32B

FIG. 2

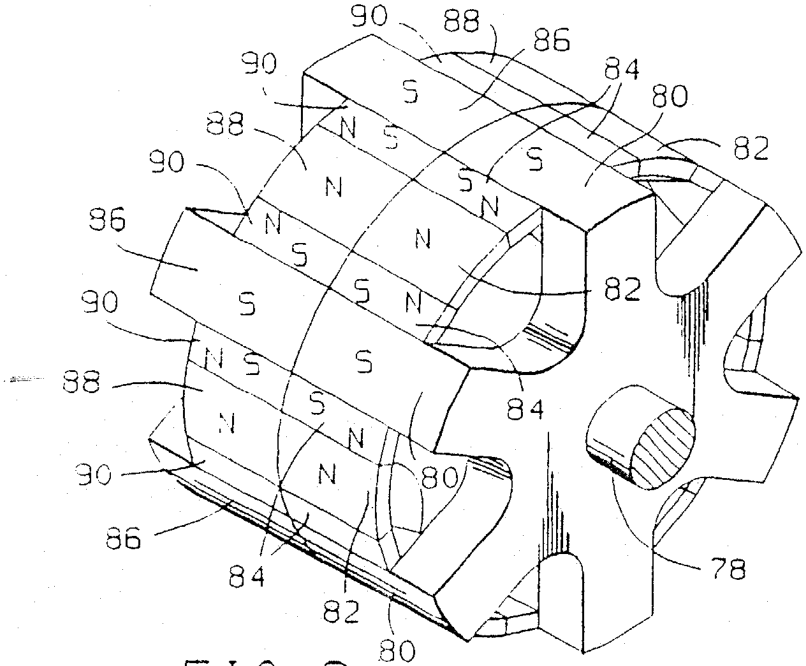

FIG. 3

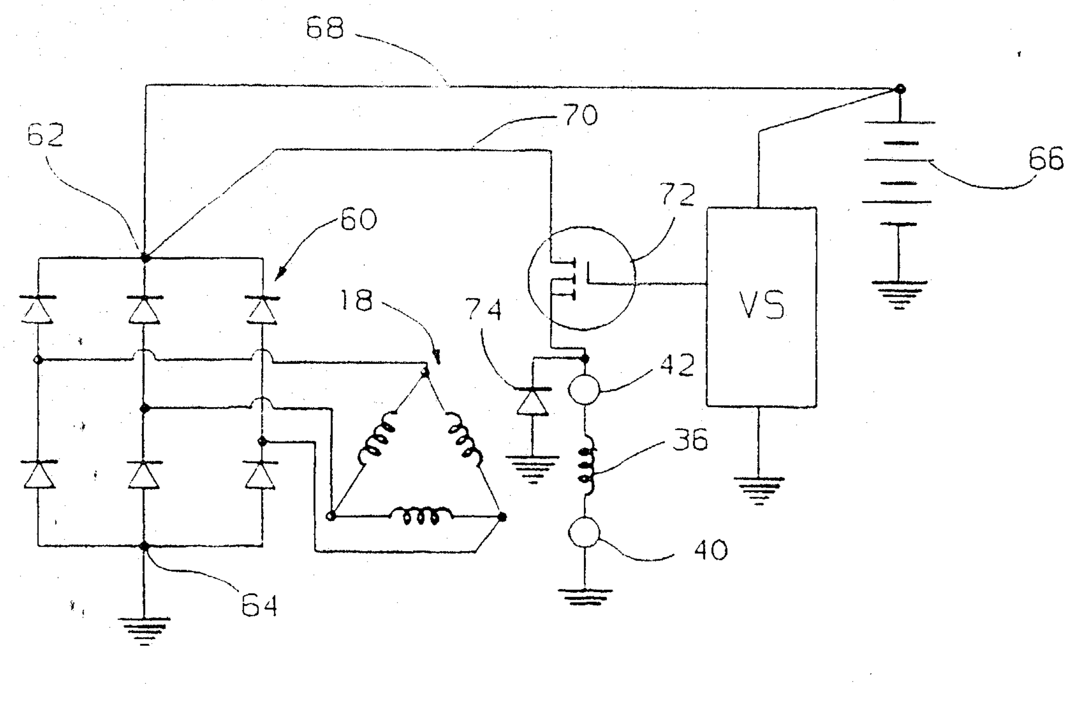

FIG. 4

European
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EUROPEAN SEARCH REPORT

Application Number

EP 90 31 1138

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X,Y	DE-B-1 209 651 (ROBERT BOSCH) * column 3, lines 11 - 18; figures 3, 4. *	1.,2.	H 02 K 21/04
D,Y	US-A-4 636 706 (BOWMAN ET AL) * column 22, line 64 - column 30, line 64; figures 1-6. *	2.	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

H 02 K
H 02 J

The present search report has been drawn up for all claims

Place of search	Date of completion of search	Examiner
The Hague	08 January 91	TIO K.H.

CATEGORY OF CITED DOCUMENTS

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